IEA HIA: A Sustainable International Framework & Strategies for Collaborative RD&D in Hydrogen Energy

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IEA HIA: A Sustainable International Framework & Strategies for Collaborative RD&D in Hydrogen Energy

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The Hydrogen Implementing Agreement (HIA) of the International Energy Agency (IEA) is an autonomous organization within the framework of the Organisation for Economic Co-operation and Development (OECD). Its purpose is to develop and promote hydrogen as a clean, renewable energy source by facilitating international cooperation and information exchange for hydrogen research, development, and design (RD&D). This paper outlines the Agreement's mission, current research portfolio and accomplishments, ongoing collaborations, and plans for the future. The IEA HIA oral presentations will highlight results of current tasks. For more information, please see www.ieahia.org and the IEA HIA Strategic Plan for 2009-2014.

IEA-HIA tasks and activities encompass the full spectrum of research issues in hydrogen production, storage, conversion, safety, integrated systems and infrastructure, as well as analysis and outreach in support of its RD&D activities. Significant technical progress has been made in these areas as a result of IEA-HIA coordinated research. After completing its most recent term of operation on 30 June 2009, the Agreement began a new phase under the Strategic Plan for 2009-2014.[1] With 21 member countries, as well as the European Commission and the United Nations Industrial Development Organization (UNIDO), the Agreement has considerable organizational capacity which, coupled with its long-standing tradition of international collaboration, position it for continued success.

The HIA's capabilities have grown with each new member. Membership increased approximately 60% during the 2004-2009 term, and the role of industry will continue to grow in the next five years. Although there are no industry sponsors in the Implementing Agreement, significant industry participation has occurred and is occurring within the tasks. UNIDO's accession is of particular significance, as it extends the IEA HIA's outreach to the developing world and its vast opportunity for sustainable energy.

The IEA-HIA Vision is for a hydrogen future in which a clean, sustainable energy supply of global proportions plays a key role in all sectors of the economy. Contemplating a new phase of expansion and progress, the IEA-HIA Executive Committee adopted the 2009-2014 Mission Statement:

Accelerate hydrogen implementation and widespread utilization to optimize environmental protection, improve energy security and promote economic development internationally while establishing the HIA as a premier global resource for expertise in hydrogen.

[1] IEA HIA End of Term Report 2004-2009 / 2009-2014 Strategic Plan, March 2009.

1 Themes & Portfolios, 2009-2014: Overview

For the period 2009-2014, the IEA HIA has identified three major themes that stem from its mission and vision. These themes are at once goals and priorities. Each theme is associated with a set of portfolios that contain tasks and activities. The themes and portfolios are listed below:

- Collaborative RD&D that advances hydrogen science and technology, including four portfolios:
  - Hydrogen Production
  - Integrated Hydrogen Systems
  - Hydrogen Storage
  - Hydrogen Integration in Existing Infrastructure
- Analysis that Positions Hydrogen for technical progress and optimization, for market preparation and deployment, and for support in political decision-making, including three portfolios:
  - Technical
  - Market
  - Support for Political Decision-making
- Hydrogen Awareness, Understanding and Acceptance that fosters technology diffusion and commercialization, including three portfolios:
  - Information Dissemination
  - Safety
  - Outreach – Inform and engage critical subsets of HIA stakeholders

(See Figure 1: IEA HIA Strategic Framework 2009-2014*)*

2 Themes & Portfolios, 2009-2014: Descriptions

2.1 Theme 1: *Collaborative RD&D*

This RD&D is the IEA-HIA's core business. It is typically medium and long-term in scope and pre-competitive in nature. The IEA HIA's study *Hydrogen Production and Storage: Gaps and Priorities* examined near, mid and long-term research needs in hydrogen production and storage.[2] The 2009-2014 Strategic Plan will address many or all of the research needs identified by the study.

2.1.1 Production Portfolio

Progress has been made in new technologies for hydrogen Production. However, Hydrogen Production and Storage: Gaps and Priorities concluded that, overall, there are significant needs for improvement in increased plant efficiency, reduction of capital costs, and reliability and operating flexibility for all production processes.

With respect to near-term options, Electrolysis and natural gas reforming are proven technologies that can be used in the early phases of building a hydrogen infrastructure. *Task 24, Wind Energy and Hydrogen Integration*, is working to efficiently combine electrolysers (a

[2] Hydrogen Production and Storage: R&D Priorities and Gaps was published by the IEA in 2006.

constant input device) with variable output wind turbines for production of hydrogen as a transportation fuel and on-site conversion of hydrogen electricity for load-balancing. Small-scale natural gas reformers remain a subject of research; there are several demonstration cases but limited commercial availability. *Task 23, Small-Scale Reformers for On-Site Supply of Hydrogen*, is investigating both technical and marketing issues related to small scale reformers, including carbon capture and storage. Task 23 has recently been extended for another year.

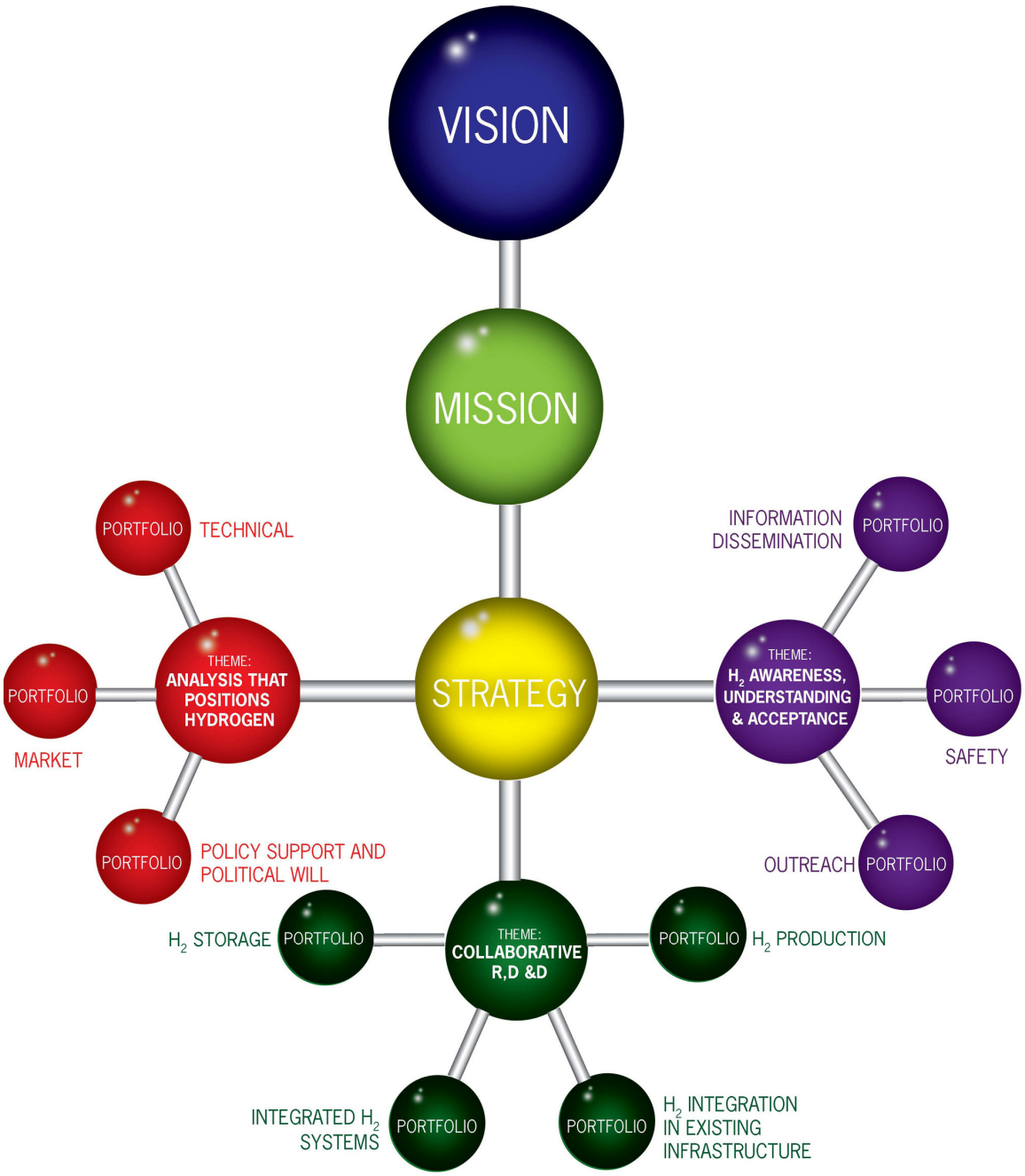


Figure 1: IEA HIA Strategic Framework 2009-2014.

Mid-term, central fossil-based production with CO_2 capture and storage could play a significant role. Research is needed on absorption and other types of separation processes as well as overall process layout and configuration. Biomass to hydrogen processes are also a mid-term option. More focus on feedstock preparation is needed. Logistics pose a challenge for this method and production appears economical only at large scale.

With respect to fossil energy carbon-containing materials, the potential for Carbon Capture and Sequestration (CCS) and pre-combustion decarbonization expand possibilities for sustainable use of these conventional resources. New efforts in this area during the 2009-2014 term may be gasification related. *Task 27, Near-Term Market Routes to Hydrogen by Co-Utilization of Biomass as a Renewable Energy Source with Fossil Fuels* addresses many of these issues.

Farther out on the time scale, basic and applied research is needed for both photoelectrolytic and biohydrogen production methods. Hydrogen production in Biological processes that entail the use of hydrogenases (enzymes) as well as genetically engineered organisms is characterized by low conversion efficiencies. Fundamental research is needed to understand the natural processes and genetic regulation involved in these reactions. It is anticipated that this work will continue through much or all of this term. *Task 21, BioHydrogen*, deals with these topics; this task is now under consideration for a three-year extension or succession by a new task. High temperature (>500ºC) production of hydrogen is also an important area of investigation for the mid and long term, focusing on materials development, high temperature membranes and heat exchangers, and High temperature electrolysis. *Task 25, High Temperature Hydrogen Production Processes*, examines solar and nuclear processes. This task was recently extended for another year.

Task 26, Advanced Materials for Waterphotolysis, is concentrating on advanced materials research related to photoelectrolytic water-splitting rather than continue at this time with design and development of photoelectrochemical (PEC) devices.

The need for continuing or additional advanced materials research was a recurring topic in the HIA's strategic assessment for 2009-2014. The need for research on catalysis was another recurring motif. Consequently, new basic and applied research activities in these areas are anticipated in this term.

As systems evolve for all types of hydrogen production methods, the HIA expects a heightened interest in applied technology research and development efforts on the componentry necessary for various hydrogen production methods.

2.1.2 Storage Portfolio

Both compressed gas and liquid hydrogen are commercially available today, but research continues to improve performance and reduce costs. R&D issues related to compressed gas include fracture mechanics, safety, compression energy, and volume. Important R&D issues for liquid hydrogen include: more efficient liquefaction, lower cost/better insulated containers, automated boil-off capture (e.g., via hydrides), re-liquefaction and volume.

For on-board hydrogen storage applications, research has focused on materials-based solid-state storage, which is currently in the development phase. The potential advantages of materials-based storage are lower volume, lower pressure (greater energy efficiency), and

higher purity of hydrogen output. Important materials storage R&D issues include: volume, weight, lower desorption temperatures, improved desorption kinetics, recharge time & pressure, heat management, cost, chemical and environmental reactivity, durability, container compatibility and optimization.

Task 22, Fundamental and Applied Hydrogen Storage Materials, is the largest hydrogen storage collaboration in the world. With over 50 projects to its credit, this task has recently been extended for another three years.

Later in this term, as storage systems meet technical targets, emphasis will shift to include R&D on componentry for all applications.

2.1.3 Integrated Systems Portfolio

Systems integration is an essential next step in collaborative hydrogen R&D. Systems integration brings component subsystems together, ensuring their efficient functioning.

Task 18, Integrated Systems Evaluation, has undertaken modeling and evaluation of a broad collection of hydrogen demonstration projects expressly for the purpose of analyzing and modeling their overall design and performance. In addition, Task 18 is the best resource for global information on all things hydrogen, including worldwide trends.

Market introduction and penetration of hydrogen technology require optimized, well-integrated systems. Therefore, as time goes on, the Agreement will focus increasing effort and attention on 1) the componentry, devices and sensors that comprise the systems; and 2) their engineering as integrated systems. This will likely translate into new activities and new tasks during the 2009-2014 term.

As an energy conversion device, the fuel cell is one of the most important hydrogen technologies, one in which the HIA has an abiding interest. As systems integration efforts advance, the HIA will certainly investigate fuel cell issues more closely, likely in cooperation with the IEA Advanced Fuel Cell Implementing Agreement.

2.1.4 Integration in Existing Infrastructure Portfolio

Future delivery of hydrogen requires the integration of hydrogen systems into the existing energy infrastructure. While that infrastructure services all sectors of the economy, the world's attention has focused first on the transport sector with its mass markets, followed by the stationary power sector. Expansion of the infrastructure will require coordination on many fronts: technology; finance and insurance; market mechanisms and policy instruments; construction and engineering; operation and maintenance; and codes and standards. While all these factors warrant attention, the HIA's focus is on RD&D issues and technical barriers—which requires research activities that interface with conventional resource chains (the grid, pipelines, trucking and other delivery systems). Likewise at issue are centralized and distributed hydrogen production, as well as mass storage.

A task on Infrastructure that will consider the hydrogen distribution network from production sites to end-users is being defined. The scope of this task is likely to feature modeling of pipelines (pumps and valves), as well as both gas and liquid mass storage above ground and underground storage in man-made and natural structures.

2.2 Theme 2: *Analysis that Positions Hydrogen*

In less than a decade, the avalanche of interest in hydrogen has been met by roadmaps and a wide array of analytic efforts on RD&D, infrastructure and market issues. Some fine analytic work on hydrogen is available today. However, a comprehensive analysis of global energy conditions that incorporates hydrogen in the world's energy future is a complex and challenging proposition, complicated by high levels of political, technical, environmental and economic uncertainty. There is, in effect, a hydrogen information gap that needs to be filled with coherent and balanced information, providing a clearer picture of hydrogen R&D needs and the future of hydrogen in the economy. Furthermore, the information needs to be appropriately packaged for specific audiences.

Therefore, the Agreement has reaffirmed its commitment to rigorous, independent analysis that supports collaborative R&D efforts and addresses the larger issue of the transition to hydrogen in the economy. This commitment amounts, in no uncertain terms, to an "Analytic Imperative." As the premier global resource for technical expertise in hydrogen energy, the IEA HIA is better positioned to offer balanced analysis on these questions than any other organization.

During the last term, the IEA HIA began the process of organizing for analysis that will address important questions about hydrogen demand, supply, and infrastructure. This process, spearheaded by the Executive Committee Analysis Group, is evolving into an Analysis Task whose definition is currently underway. The Executive Committee expects that development of analysis products will not only contribute to filling the information gap but also more firmly establish the HIA as the leading technical resource in hydrogen. The Agreement expects to cooperate closely on IEA analytic efforts such as the well-regarded Energy Technology Perspectives (ETP) and the World Energy Outlook (WEO) publications.

The Analysis theme contains three portfolios: technical, market and support for political decision-making. Collectively, these three portfolios will provide the analyses needed to provide relevant stakeholders and policy-makers with balanced information that stimulates RD&D, market adoption and widespread application of hydrogen.

2.2.1 Technical Portfolio

The technical portfolio comprises analysis intended, first and foremost, to promote advancement and optimization of the technology. This effort is also intended to ensure that the HIA provides a clear picture of evolving hydrogen RD&D needs.

There is a larger need to make a cross-cutting technical case for all hydrogen technologies, including production, storage, conversion (*e.g.* fuel cell) delivery and infrastructure. This effort will be based in the Analysis Task. The foundation for the effort is underway in the form of a literature review and gap analysis.

2.2.2 Market Portfolio

The market portfolio of analysis activities will deal expressly with issues of market preparation and deployment. These issues include the topic of market transformation that supports the deployment of innovative technology, bridging the early, and often fatal, stage of market introduction and the later stage of market penetration. The analytic market portfolio

effort will make the business case for hydrogen, positioning hydrogen for competitive advantage in the marketplace. This analysis will entail both supply and demand side assessments, including the non-energy sector. The supply side analysis will incorporate a market perspective. Techno-economic analysis with a market perspective will be performed on individual technologies.

2.2.3 Support for Political Decision-Making Portfolio

Recognizing that public policy will play a crucial role in development of hydrogen technology and its deployment in the marketplace, and that support for political decision-making is considered indispensable to a future with hydrogen energy, the Executive Committee approved the Support for Political Decision-Making Portfolio to undertake analysis that aligns investment in hydrogen technology with global public policy concerns (notably climate change and emissions reduction). Wherever appropriate, this analysis will utilize findings and conclusions from the Agreement's technical and market analyses. The results will be presented in position papers and briefs.

2.3 Theme 3: *Hydrogen Awareness, Understanding & Acceptance*

This theme complements the HIA's principal theme - Collaborative R&D, and its supporting theme - Analysis. It acknowledges that awareness, understanding and acceptance are requisite to technology diffusion and commercialization. It recognizes that the benefits of hydrogen must be articulated to stakeholders and decision makers. And it accepts a major role for the HIA in the communications process. Through this three-portfolio effort to foster technology diffusion and commercialization, the HIA expects to increase its visibility as the reference institute for hydrogen.

2.3.1 Information Dissemination Portfolio

The ultimate success of the "Analysis Imperative" depends upon effective information dissemination. This function targets key stakeholders in the science, energy and environmental communities, as well as the media, government and industry. The IEA is itself an important target audience, and the Agreement will also disseminate information beyond the borders of IEA member countries. UNIDO, a new IEA HIA member, is expected to both contribute to and benefit from information dissemination activities.

At the task level, Agreement Experts have produced over 1,000 HIA related publications/reports and 1,000 HIA related presentations during the 2004-2009 term. The trend toward increased production of information in publications/reports and presentations is expected to continue. As hydrogen progresses toward commercialization during the 2009-2014 term, the HIA newsletter (IEA HIA News) will evolve to focus more on hydrogen demonstrations and the hydrogen marketplace. The IEA HIA now develops and disseminates information via its Website, Annual Report, newsletter, and brochures in addition to its extensive technical reports and publications.

The Agreement's conference program facilitates preparation and delivery of abstracts, papers, exhibits, and related presentations. During the 2009-2014 term, the HIA expects to create new technology platforms and channels for information dissemination (e.g. Webinars and podcasts).

2.3.2 Safety Portfolio

Hydrogen safety and consumer comfort with hydrogen are vital ingredients for its acceptance. Hydrogen safety considerations cut across all HIA RD&D portfolios. *Task 19, Hydrogen Safety*, explicitly deals with safety through analysis, testing and the development of target information products. During this term, as safety information products become available, Task 19 plans to distribute them as broadly as possible. The Secretariat will participate directly in distribution and promotion of Task 19 safety products and will incorporate Task 19's safety findings into other Agreement communications whenever possible. Additional safety activities – one or more tasks – are projected for the new term. Precise topics will be defined as Task 19 nears its 2010 conclusion; the regulatory framework for codes and standards will likely be included.

2.3.3 Outreach Portfolio

This portfolio goes beyond information dissemination to both inform and engage a critical subset of IEA-HIA stakeholders and decision makers. Engagement may take several forms, including participation as an IEA-HIA Expert, a member, or possibly a sponsor. Engagement may also imply cooperation on a more limited timeframe or for a particular purpose.

To engage important target audiences, such as industry, government, and members of the renewable energy community, the Outreach Portfolio employs the full array of IEA-HIA information products and all available channels, including networking opportunities. Active participation of the Executive Committee Members, Operating Agents, and the Secretariat, who are well-positioned to carry out these activities in strategic situations around the world, is considered essential.

Many of the world's leading experts in hydrogen energy RD&D have partnered with the HIA since its inception. We are pleased to recognize their dedication and innovation with two new prizes: the IEA HIA Individual Prize and IEA HIA Project Prize.[3] The IEA HIA Individual Prize was created to celebrate hydrogen research and development distinguished by technical excellence and harmony in international cooperation that contributes to the understanding and advancement of basic and applied science.

The Agreement awarded its inaugural IEA HIA Individual Prize in June 2008 to Dr. Gary Sandrock. Although the Individual Prize was conceived as a single award, the Executive Committee decided that special circumstances warrant special measures: the late Dr. Tapan Kumar Bose, who passed away in 2008, was honored as the recipient of a IEA HIA Memorial Prize for lifetime achievement in hydrogen R&D. The first IEA HIA Project Prize will be awarded at the 2010 World Hydrogen Energy Conference, and the next Individual Prize may also be awarded in 2010.

3 Tasks, 2009-2014: Overview

Over the course of its thirty-two-year history, the IEA HIA has created a broad portfolio of twenty-seven (27) tasks, nine of which are operating presently, while others are still being

[3] The Executive Committee selects Individual Prize winners from nominations proposed by its members, and from members and Operating Agents in the case of the Project Prize.

defined. For each operational term of, the HIA's tasks correspond to its assessment of the hydrogen energy community's direction, priorities, and RD&D requirements.

The tables below review the tasks' accomplishments of the recent past (Figures 2-4), the Agreement's prospective schedule of tasks and Plan of Work (Figure 5), and Key Issues for the 2009-2014 term (Figure 6).

Figures 2-4 outline accomplishments of the twelve tasks operating during the 2004-2009 term, four of which are now complete. They reflect the Agreement's work for the last five years on pre-commercial collaborative RD&D on Hydrogen Production and Storage, and Assessment of the Market Environment.

Figure 2: Production RD&D Programs, 2004-2009.

Advancement of Science and Technology **via pre-commercial collaborative** Production RD&D **programs**	
Task	**Accomplishments, Benefits and Success Stories in Completed Term**
Task 15 Photobiological Production	**R&D Progress toward development of H_2 production by microalgae** • A novel, sustainable photobiological production of molecular hydrogen upon a reversible inactivation of the oxygen evolution in the green alga *Chlamydomonas reinhardtii* (Subtask A) • Identification of accessory genes and gene products necessary for the photoproduction of H_2 in *Chlamydomonas reinhardtii*. Finding that STA7 and starch metabolism play an important role in *C. reinhardtii* H_2 photoproduction. (Subtask A) • Identification and characterization of *tla1*, a novel gene involved in the regulation of the Chl antenna size in photosynthesis in *C. reinhardtii* (Subtask B) • The generation of 11.6 mol of H_2 per mol of glucose-6-phosphate using enzymes of the oxidative pentose phosphate cycle coupled to a hydrogenase purified from *Pyrococcus furiosus* (Subtask C) • The development of both smaller and larger Photobioreactors (Subtask D).
Task 16 Hydrogen from Carbon-Containing Materials	• **State of the Art reports for all three** Task 16 **subtasks**: **Subtask A** on the potential for cost reduction of large-scale processing from natural gas with pre-combustion de-carbonization of fossil energy; **Subtask B** on prospects for H_2 from biomass **from an industry perspective; and Subtask C on small-scale reformer technology** for distributed near to medium term H_2 supply. • **Substantial industry participation** on a challenging scope of work was an HIA first that serves as a benchmark for future industry participation
Task 20 Hydrogen from Waterphotolysis	• Development, acceptance and operation of two multi-year R&D PEC programs, one at the U.S. DOE and the other, called "NanoPEC" under EU 7th Framework Program • Pioneered Fe_2O_3 (Hematite) as very promising, abundant, low-cost and environmentally benign photoanode material. • Maturing PEC water-splitting tandem concepts • Photoelectrochemical (PEC) work on tungsten trioxide led to development of novel, highly sensitive, reliable and low-cost **pollution control sensors for auto industry**
Task 21 BioHydrogen	• Better genomic understanding of hydrogen-producing strict anaerobes • New assessment method for overall analysis of BioHydrogen (Subtask D) has been screened
Task 23	• Contributing to development of norms for small-scale reformers to

Advancement of Science and Technology **via pre-commercial collaborative** Production RD&D **programs**	
Small-Scale Reformers for On-Site Hydrogen Supply (SSR for Hydrogen)	harmonize industrialization. This effort, which includes carbon capture, is crucial to development of the hydrogen infrastructure and future distributed generation capability • Subtask 3 Market Studies stand to materially facilitate HIA analysis efforts • Fast-tracking the deployment process of market introduction and penetration of small-scale reformers for on-site hydrogen supply from multiple feedstocks, fossil and renewable
Task 24 Wind Energy and Hydrogen Integration	• Setting the stage for large-scale use of renewable wind energy for hydrogen production in the near future by addressing the entire wind to hydrogen production chain from technical, economical, social, environmental, market and legal perspectives • Exploring in detail possible applications for hydrogen, especially full wind & hydrogen integration by means of hydrogen storage and electrical conversion that balances the original wind energy production, allowing an approach to demand that closes the gap with conventional energies.
Task 25 High Temperature Production of Hydrogen	• Poised to elaborate world-wide knowledge on specific high temperature (>500ºC) processes (solar and nuclear) that will support production of massive quantities of zero-emission hydrogen • Producing **summary sheets** on high temperature processes in **general and detailed** versions
Task 26 ***NEW***	On track to create data base on advanced materials for waterphotolysis

Figure 3: Storage RD&D Programs, 2004-2009.

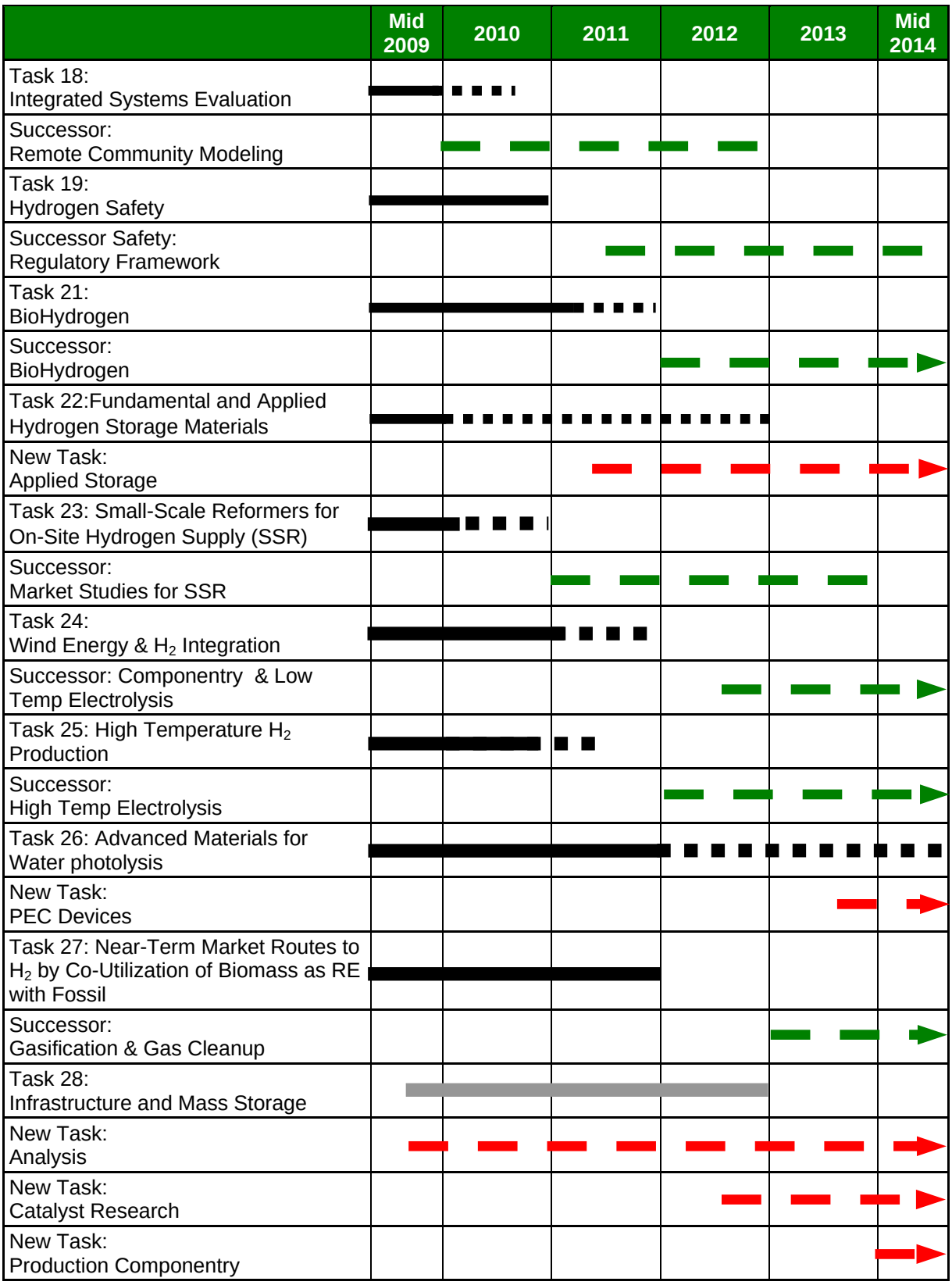
Advancement of Science and Technology **via pre-commercial collaborative** Storage RD&D **programs**	
Task	**Accomplishments, Benefits and Success Stories in Completed Term**
Task 17 Solid & Liquid State Storage	• Evolved into largest global R&D collaboration on hydrogen storage materials of its time, contributing to R&D, information dissemination and transfer of technology • Huge contribution to the literature with 900+ publications and presentations plus 17 patents
Task 22 Fundamental and Applied Hydrogen Storage Materials	• World's largest collaboration to-date on hydrogen storage materials R&D • Biannual week long Task 22 meetings serve as the ultimate global forum for expert cooperation on hydrogen storage R&D (emphasizing materials and the transportation sector), the grand challenge in hydrogen. As of December 2008 it produced 450+ publications/articles, 450+ presentations and 16 patents.

Figure 4: Assessment of Market Environment Programs, 2004-2009.

Assessment of Market Environment **including non-Energy Sector; and Analysis, Safety and Economics**	
Task 18 Integrated Systems Evaluation	World's best address for worldwide information and analysis on hydrogen and integrated systems • Database with 200+ National Documents • National Organizations database • National Projects database • State of the art analysis entitled Demonstration Project Evaluations - Used technical simulations that may be applied to other projects to replicate results - General conclusions in critical areas of system evaluations, data monitoring, modeling tools, system design, control systems and cost-benefit analysis • Synthesis, lessons learned and trend analysis relate to permitting, funding and technology performance • More than a dozen relevant case studies
Task 19 Hydrogen Safety	• Contribution to global understanding of H2safety through studies and databases laying foundation for codes and standards • Phase 1 laid theoretical groundwork for phase two testing program to evaluate the effects of equipment or system failures under a range of real life scenarios, environments& mitigation measures • Subtask A Activity 1 produced a Survey of Hydrogen Risk Methods in Phase 1 • Subtask A Activity 2 produced Comparative Risk Assessment Studies of Hydrogen and Hydrocarbon Fuelling Stations • Subtask A Activity 3 produced a Knowledge Gaps White Paper

Figure 5 sets forth a timeline for the Agreement's tasks and activities projecting through 2014. In summary, nine (9) tasks are presently active (December 2009); six (6) of the existing tasks are expected to be extended during the term; and seven (7) tasks are expected to be formed as successors to current tasks. Five (5) new tasks are forecast; significant progress has already been made in formulating new tasks (whether successors to existing tasks or new work).

Figure 5: IEA HIA Work Program Timeline, Current and Proposed/Future Tasks.



Key to Work Plan above:

- Solid black line = current task
- Solid grey line = task in definition
- Short dash broken line = task extension
- Long dash green black broken line = successor task
- Long dash red broken line = new task
- Arrow at end = means task is expected to continue after end of 2014 term

3.1 Work Program Table

Figure 6 is organized by theme & portfolio, and outlines the tasks' key issues & broad "approach." Tasks that have been proposed as potential additions to the Program of Work during the 2009-2014 term are featured in some portfolios' bottom sections. For context, you may refer to Figure 1: IEA HIA Strategic Framework 2009-2014

Figure 6: Plan of Work, 2009-2014.

	THEME & PORTFOLIO	KEY ISSUES	APPROACH In place 2009	APPROACH Proposed/Potential
FUNDAMENTAL		• Anaerobic use of bacterial dark fermentations and photosynthetic microbes; increased yields; biomimetics; biohydrogen acceptance	• Task 21, BioHydrogen	• Extend Task 21 past 2010
		• Advanced materials for photo-electrochemical (PEC) watersplitting • Advanced materials (catalysts) for other production methods	• Task 26, Advanced Materials for Waterphotolysis	• Possible extension of Task 26 past 2011 • Task on catalyst research for other production methods
		• High temperature production from nuclear and solar • Electrolysis	• Task 25, High Temperature Production	• Possible extension of Task 25 • High temperature electrolysis activity
TECHNOLOGY	**RD&D** ***Production*** 	• Biofuels for reformers; CCS & emission handling • Gasification and gas clean-up • Design/development of photo-electrochemical (PEC) devices • Fully integrated wind and H_2 application • Co-gasification of biomass with fossil fuels; tradable intermediates	• Task 23, Small-Scale Reformers for On-Site Supply of Hydrogen • Task 24, Wind Energy and Hydrogen Integration • Task 27, Near-Market Routes to Hydrogen by Co-utilisation of Biomass as a Renewable Energy Source with Fossil Fuels	• Possible one year Task 23 extension past 2009 • Task on Purification/ separation, ICE for on-site reformers • Possible successor to Task 26 on development of PEC devices • Possible Task 24 extension • Follow-up activities/ successor task on low temperature electrolysis • Follow-on efforts TBD

Figure 6: Plan of Work, 2009-2014, *continued.*

	THEME & PORTFOLIO	KEY ISSUES	APPROACH In place 2009	APPROACH Proposed/Potential
FUNDAMENTAL	**RD&D** ***Storage*** H_2 STORAGE PORTFOLIO	• Reversible / regenerative H_2 storage media fulfilling int. targets • Fundamental & engineering understanding • Materials for stationary applications • Compression • Metal Embrittlement	• Task 22, Fundamental and Applied H_2 Storage Materials Development	• Task 22 seeking 2-3 year • Extension past 2009; there- • After, disposition of • activity TBD • Possible Task/activities on H_2 interactions with materials
TECHNOLOGY		• Applied Aspects of H_2 storage systems in vehicles: compressed gas, liquid and materials-based;		• New task examining • Technologies for H_2 storage: • Compressed gas, liquid and • Materials-based; Techno-economic analysis of alternatives. • Component task
	RD&D ***Integrated Systems*** PORTFOLIO INTEGRATED H_2 SYSTEMS	• All purpose information on H_2 integration • Harmonization of components for reformer systems; technology performance and cost; CCS & emission handling • Specifications for Integrated Systems	• Task 18, Integrated Systems Evaluation • Task 23, Small-Scale Reformers for On-Site Supply of Hydrogen • Task 24, Subtask B	• Possible continuation of • Current modeling and • Analysis of demonstration • systems • Possible one year extension of Task 23 • New Task H_2 Communities • Modeling and Design: islands, remote, and rural communities • Possible one year Task 23 extension past 2009
	RD&D *H_2 Integration in Existing Infrastructure*	• Geologic storage, pipelines, and "mass" storage	• In Definition: Infrastructure and Mass Storage Task	• TBD

Figure 6: Plan of Work, 2009-2014, *continued.*

	THEME & PORTFOLIO	KEY ISSUES	APPROACH In place 2009	APPROACH Proposed/Potential
CROSSCUTTING	 **Analyses that position H_2** *Technical* 	• "Where will the H_2 come from?" • What role will H_2 play? • Develop a balanced view • Competition in transport sector	• Analysis Group • Task 18 – H_2 Literature Review	• Analysis Task: Supply/Demand • Comprehensive report that includes CO_2 reduction based on introduction of H_2 technology • Proactive cooperation with IEA analytics • Part of proposed storage task: Techno-economic analysis of alternatives in automotive industry.
	Analyses that position H_2 *Market* 	• "Where will the H_2 come from?" • What role will H_2 play? • Include non-energy sector	• Analysis Group • Task 23, Subtask 3 Market Studies • Task 24, Subtask C and D, Business Concept Development • Task 27, Subtask D, Roadmap Development and Verification	• Analysis Task: Supply/Demand from a market perspective – a comprehensive report that includes CO_2 reduction market, cap & trade • Proactive cooperation with IEA analytics • Successor task on Market Studies for on-site reformer technology
	Analyses that position H_2 *Support for Political Decision-making* 	• Lack of information and clarity about the benefits of hydrogen (notably, CO_2 and pollution reduction) among stakeholders and decision makers whose influence is needed and useful for R&D, planning, demonstration and deployment		• Analysis Task: Briefs and position papers to address all issues, including CO_2 reduction, climate change

Figure 6: Plan of Work, 2009-2014, *continued.*

	THEME & PORTFOLIO	KEY ISSUES	APPROACH In place 2009	APPROACH Proposed/Potential
CROSSCUTTING	 **H_2 Awareness, Understanding and Acceptance** *Information Dissemination* 	• Broader and deeper information dissemination needed along with targeted dissemination.	• An element of the Outreach Program managed by Secretariat, it features: • IEA HIA Website • Annual Report • Conference strategy • Communication / Promotion materials • Public relations and media • Contributions to IEA events and • publications • Target audiences include: IEA member countries and IEA family • Gleneagles "+5" and potential H_2 members • Hydrogen community	• Increase information dissemination by continuing current activities and augmenting with: Enhanced conference strategy that features HIA seminars / workshops <200; and possible sponsorship of larger conference; webinars, possible pod-casts and other IT vehicles dissemination of safety products dissemination of analysis products cooperation with ETDE to expand market for information • Expand target audiences: Non-IEA member countries, developing world, and greater energy community
	H_2 Awareness, Understanding and Acceptance *Safety* 	• All aspects of hydrogen safety and consumer comfort with hydrogen	• Task 19	• Task 19 concludes in 2010. • High potential for multiple follow-up tasks in key areas. Definition of successor tasks to occur early in term. • Task 19 to complete information products and distribute with Secretariat support.
	H_2 Awareness, Understanding and Acceptance *Outreach*	• Inform and engage	• An element of the Outreach Program directed by ExCo and managed by the Secretariat.	• Inform and engage through information dissemination and targeted networking; build participation; influence stakeholders and decision makers. • **Potential Participants**: Members, experts, sponsors • **Stakeholders and Decision Makers**: IEA, IEA member countries; IEA non-member countries; Government & Industry; Hydrogen Community; Renewable Community

4 Conclusion and Final Remarks

The IEA HIA is in a period of growth and is well-positioned for continued success in its core business of collaborative RD&D, as well as analysis for technical optimization and market preparation, and hydrogen community outreach.

The Agreement is the world's premier global resource for technical expertise in hydrogen RD&D, offering its members a **Value Proposition** that facilitates world-class research and increases their impact. Members benefit from the Agreement's:

- **Neutral international profile:** The Agreement is a reliable, unbiased forum through which Members may access technical experts and achieve global reach to engage governments, academia, and industry.
- **Leveraged global resources:** Members may engage an established network of researchers and shared resources in the areas of science and technology, market analyses and outreach. The IEA-HIA Portfolio includes shorter term and long-term, pre-competitive activities. In all cases, intellectual property (IP) is treated with care.
- **Track record of success:** For 30+ years, IEA-HIA Tasks have facilitated collaborative research, and its membership continues to grow.

IEA HIA Experts who are presenting at the 2010 World Hydrogen Energy Conference will discuss the latest work of the Tasks, including recent results achieved since this paper's publication. Look for their 2009-2010 work in areas of renewed interest, such as hydrogen safety and market analysis, as well as their continuing advancements in hydrogen storage and production.

Epilogue

Since the November 2009 timeframe when this paper was prepared, the IEA HIA has marked several noteworthy milestones.

Four milestones are associated with the 2009-2014 Strategic Plan's Collaborative R,D&D theme. *Task 18 – Integrated Systems Evaluation*, part of the Integrated Systems Portfolio, was completed. *Task 21- BioHydrogen*, part of the H_2 Production Portfolio theme, was extended for a five year period (three years firm with an additional two year option). Task 28 – Large-Scale Hydrogen Delivery Infrastructure was approved as part of the Integration in Existing Infrastructure Portfolio. *Task 29 - Distributed and Community Hydrogen*, part of the Integrated Systems Portfolio, received preliminary approval.

With respect to the theme of Analysis that Positions Hydrogen, *Task 30 – Global Hydrogen Systems Analysis*, was approved.

The IEA HIA awarded its inaugural Project Prize 20 May during the Closing Ceremony of the World Hydrogen Technology Conference (WHEC) in Essen, Germany. Two Project Prizes were awarded. For Fundamental Research, the winner is Fundamental Safety Testing and Analysis of Hydrogen Storage Materials and Systems (H-25), a project of IEA HIA *Task 22 Fundamental and Applied Hydrogen Storage Materials Development*. For Technology Demonstration, the winner is ITHER (Infraestructura Tecnologica del Hidrogeno y Energias Renovables), a project of IEA HIA *Task 24 Wind Energy and Hydrogen Integration*.